CLAIMS

We claim:

1. A NO_x reduction method comprising:

treating a first gas comprising NO_x, wherein x is greater than zero, and producing a second gas comprising NO_2;

reducing a portion of the NO_2 in the second gas to N_2 and producing a third gas comprising less NO_x than the first gas, substantially all of the third gas NO_x being NO;

treating the third gas and producing a fourth gas comprising NO_2; and

reducing a portion of the NO_2 in the fourth gas to N_2 and producing a fifth gas comprising less NO_x than the third gas, substantially all of the fifth gas NO_x being NO.

2. The method of claim 1 wherein treating the first gas occurs separately from reducing NO_2 in the second gas, and wherein treating the third gas occurs separately from reducing NO_2 in the fourth gas.

3. The method of claim 1 wherein the method further comprises:

treating the fifth gas and producing a sixth gas comprising NO_2; and

reducing a portion of the NO_2 in the sixth gas to N_2 and producing a seventh gas comprising less NO_x than the fifth gas, substantially all of the seventh gas NO_x being NO.

4. The method of claim 1 wherein the first and third gases further comprise hydrocarbon, wherein treating the first gas and reducing a portion of the NO_2 in the second gas provides oxidation of less than 50 volume percent (vol%) of the hydrocarbon in the first gas, and wherein treating the third gas and reducing a portion of the NO_2 in the fourth gas provides oxidation of less than 50 vol% of the hydrocarbon in the third gas.

5. The method of claim 4 comprising oxidizing less than 35 vol% of the hydrocarbon in the first and third gases.

6. The method of claim 1 wherein a fraction of the first gas NO_x treated to NO_2 in the second gas approximately equals a fraction of the third gas NO_x treated to NO_2 in the fourth gas.

7. The method of claim 1 wherein the portion of second gas NO_2 reduced is less than about 70 vol%.

8. The method of claim 7 wherein the portion of second gas NO_2 reduced is from about 50 vol% to about 60 vol%.

9. The method of claim 1 wherein all of the third and fifth gas NO_x is NO.

10. A NO_x reduction method comprising:

treating a first gas comprising NO_x, wherein x is greater than zero, with a first plasma and producing a second gas comprising NO_2;

reducing a portion of the NO_2 in the second gas to N_2 with a first catalyst and producing a third gas comprising less NO_x than the first gas, substantially all of the third gas NO_x being NO;

treating the third gas comprising NO_x with a second plasma and producing a fourth gas comprising NO_2; and

reducing a portion of the NO_2 in the fourth gas to N_2 with a second catalyst and producing a fifth gas comprising less NO_x than the third gas.

11. The method of claim 10 wherein treating the first gas occurs separately from reducing NO_2 in the second gas, and wherein treating the third gas occurs separately from reducing NO_2 in the fourth gas.

12. The method of claim 10 wherein treating the first gas occurs together with reducing NO_2 in the second gas.

13. The method of claim 10 wherein the method further comprises:

treating the fifth gas with a third plasma and producing a sixth gas comprising NO_2; and

reducing a portion of the NO_2 in the sixth gas to N_2 with a third catalyst and producing a seventh gas comprising less NO_x than the fifth gas.

14. The method of claim 10 wherein substantially all of the fifth gas NO_x is NO.

15. The method of claim 10 wherein the first and third gases further comprise hydrocarbon, wherein treating the first gas and reducing a portion of the NO_2 in the second gas provides oxidation of less than 50 vol% of the hydrocarbon in the first gas, and wherein treating the third gas and reducing a portion of the NO_2 in the fourth gas provides oxidation of less than 50 vol% of the hydrocarbon in the third gas.

16. The method of claim 15 comprising oxidizing less than 35 vol% of the hydrocarbon in the first and third gases.

17. The method of claim 10 wherein a fraction of the first gas NO_x plasma treated to NO_2 in the second gas approximately equals a fraction of the third gas NO_x plasma treated to NO_2 in the fourth gas.

18. The method of claim 10 wherein the portion of second gas NO_2 reduced is less than about 70 vol%.

19. The method of claim 18 wherein the portion of second gas NO_2 reduced is from about 50 vol% to about 60 vol%.

20. The method of claim 10 wherein all of the third and fifth gas NO_x is NO.

21. The method of claim 10 wherein the first catalyst exhibits a composition the same as the second catalyst.

22. The method of claim 10 wherein the method further comprises controlling energy consumption of the first and second plasmas independent of each other.

23. The method of claim 22 further comprising substantially minimizing a combined energy consumption of the first and second plasmas.

24. A NO_x reduction method comprising:

performing a step at least three times in series, the step comprising converting NO_x, wherein x is greater than zero, comprised by an inlet gas to NO_2 with a plasma and catalytically reducing NO_2 at least to N_2 and NO comprised by an outlet gas; and

operating the at least three performances of the step to plasma convert approximately equal fractions of the inlet gas NO_x to NO_2.

25. The method of claim 24 wherein the at least three performances of the step are substantially identical.

26. The method of claim 24 further comprising substantially minimizing a combined energy usage of the plasma conversion for the at least three performances of the step.

27. The method of claim 24 wherein the outlet gas of at least two of the three performances of the step comprises the inlet gas for a subsequent performance of the step.

28. The method of claim 24 wherein the step further comprises oxidizing hydrocarbon from the inlet gas, the outlet gas containing greater than 50 vol% of the hydrocarbon from the inlet gas.

29. The method of claim 28 comprising oxidizing less than 35 vol% of the hydrocarbon in the inlet gas.

30. A NO_x reduction apparatus comprising:

a plurality of reactor units in series, individual reactor units comprising a plasma device and a reducing catalyst, the plasma device exhibiting the property of converting NO_x, wherein x is greater than zero, to NO_2, and the reducing catalyst exhibiting the property of reducing NO_2 to a reaction product consisting essentially of N_2 and NO.

31. The apparatus of claim 30 wherein the plasma device and reducing catalyst are separated.

32. The apparatus of claim 30 wherein the plasma device of at least one of the reactor units further comprises additional reducing catalyst in a plasma region.

33. The apparatus of claim 30 wherein the reaction product consists of N_2 and NO.

34. The apparatus of claim 30 wherein at least one of the plurality of reactor units exhibits the property of oxidizing less than 50 vol% of hydrocarbon input.

35. The apparatus of claim 34 wherein the at least one reactor unit oxidizes less than 35 vol% of the hydrocarbon input.

36. The apparatus of claim 30 wherein the NO_2 reduced to N_2 is less than about 70 vol%.

37. The apparatus of claim 36 wherein the NO_2 reduced is from about 50 vol% to about 60 vol%.

38. The apparatus of claim 30 wherein the reactor units' catalysts exhibit a same composition.

39. The apparatus of claim 30 further comprising a plurality of separate power control devices for respective plasma devices of individual reactor units.

40. The apparatus of claim 30 wherein the plurality of reactor units comprises three reactor units.

41. The apparatus of claim 30 wherein the plasma devices comprise dual dielectric barrier discharge devices.

42. The apparatus of claim 30 wherein the reducing catalysts comprise at least one of barium zeolite Y type and sodium zeolite Y type.